of saturation have been obtained by Samuel Fortier (see Engineering Record of April 15, 1905, p. 430).

Additional experimental data along this line would be of the utmost practical and economic value, not only in relation to the ordinary problems of hydrology in estimating stream flow, but also in relation to irrigation, land drainage, and agricultural engineering in general. The writer has designated the ratio of the actual evaporation rate from a soil surface at any given time and with any degree of saturation to the evaporation rate from water or a saturated soil surface as the "evaporation opportunity."[1]

It so happens that in long periods of drought, when the evaporation rate from a saturated surface is highest, the evaporation opportunity from the soil surface decreases. It is a natural result of these opposing influences that there is some particular amount and distribution of rainfall in any locality for which the total evaporation loss from the soil is a maximum. Although this is important, the writer does not think that it has ever hitherto been pointed out. Strangely enough, it follows as a simple mathematical deduction from a number of existing formulas for calculating run-off and, furthermore, it is abundantly confirmed by experience, inasmuch as it will be found that if almost any long-term record of rainfall and stream flow is analyzed, and the results are plotted in terms of water losses against precipitation, the resulting water losses will have a maximum for an annual rainfall which generally lies between 45 and 75 inches in England and the eastern United States.

This calls attention to the fact that the older ideas and methods of expressing run-off as a percentage of rainfall are essentially fallacious, and if engineers are to justify public confidence with regard to their ability to predict safely the available yield of water-supplies, their work must, in the future, be founded upon the use of meterologic data now often ignored and upon more rational and detailed methods of analyzing and utilizing such data.

[1] "Relative evaporation" or "Evaporativity" might be a more suggestive designation. See MONTHLY WEATHER REVIEW, Jan. 1919, 47:30.—EDIT.

ELEMENTS OF HYDROLOGY.

By ADOLPH F. MEYER, C. E., Associate Professor of Hydraulic Engineering, University of Minnesota.

[John Wiley & Sons (Inc.), New York, 1917, pp. 487, 287 figs.]

This volume is a welcome addition to our knowledge of hydrology and its practical application. It was prepared for the use of professional men, teachers and students of engineering, and aims to set forth the fundamental data and considerations rather than to provide a text book.

After defining hydrology and its applications the author presents in Chapter II a résumé of the physical properties of the atmosphere with a more or less condensed account of the variations of the several meteorological elements, closing with a brief reference to the general circulation of the atmosphere as manifested in the winds. Chapter III is devoted to a consideration of water, its various states and properties. Chapter IV on precipitation is a very complete résumé of the essential facts concerning the occurrence of precipitation and its geographic distribution. The remaining chapters deal with evaporation, from land and water surfaces transpiration, deep seepage, run-off, stream-flow data, supplementary stream-flow data, and modification of stream flow by storage.

The book is unusually rich in illustrative material, drawn largely from Federal and State reports, from private sources, as well as from the author's original investigations.—*A. J. H.*

THE WEATHER AND DAILY STREAM FLOW FOR HYDRO-ELECTRIC PLANTS.

By J. CECIL ALTER, Meteorologist.

[Dated: Weather Bureau, Salt Lake City, Utah, Apr. 11, 1919.]

SYNOPSIS.—The important part played by daily weather forecasts in the problem of water regulation for hydroelectric plants in Utah is brought out in this paper. The writer compares this work with the daily prediction of water stages on eastern rivers. As many of the hydro-electric plant reservoirs are located at least 36 hours' travel (measured by stream flow) from the plants themselves, it is of great importance that weather conditions, particularly as regards precipitation, be accurately known 36 hours in advance. If, for example, rain is expected at the end of any given period of 36 hours the reservoir outlet can be closed and the precious water saved until needed. On the other hand, if a period of dry weather is expected to set in at the end of 36 hours, the outlet at the reservoir must be opened so that the plant will have an abundance of water. These conditions apply equally well to irrigation control.—H. L.

Daily weather forecasts and general meteorological data have for some time entered rather largely into the problem of water regulation for the 27 hydro-electric plants of the Utah Power & Light Co., in northern Utah, and southeastern Idaho, as managed by Maj. Cooper Anderson, superintendent of the power department. The general problem bears some analogy to the daily prediction of water stages on eastern rivers, but many additional factors require serious consideration.

All but four of the plants mentioned are located on the smaller streams coming out of the Wasatch Mountains, the flow of which can be relied upon for running the plants to machine capacity only in the flood time; this is from about March to early June, inclusive, when mountain snow is melting most rapidly, and when precipitation is normally heaviest. During the remainder of the year many of these plants are subject to greatly decreased output for want of water.

In summer and autumn the water supply from snow stores in the mountains reaches a minimum, and this is normally the period of lightest precipitation in this region. A sustained stream flow, ample for power production purposes, occurs in these months only when previous snowfall and current precipitation are abnormally heavy. In winter the tributaries are closed by ice with the first hard freeze, the frost gradually sealing the larger feeders, and finally the trunk stream if the weather be very severe.

It is essential that these scattering plants be operated as fully as possible, because of their nearness and convenience to purchasers of the power produced; and inasmuch as the company provides by far the greater percentage of all electricity used by the mining, smelting, interurban and street railway, sugar refining, city lighting, and other companies in this district, which includes Salt Lake City, Ogden, and probably a score of smaller towns, the demands for current are very exacting.

However, by an extensive network of transmission lines throughout the region, any one plant or series of plants may be closed down, and its customers supplied without interruption of service by other plants. In fact, since so much depends on the elements in critical seasons provision is made for the emergency closing of more than one-half the smaller plants, in the installation of four mammoth plants on Bear River, the largest stream in the region, which have a production capacity of about 70 per cent of the average requirements of the entire system.

This stream is much more dependable, by reason of its length and size, than the smaller streams; but like all streams dependent on mountain snowfall, its spring freshet curve is followed by a serious decline. Therefore Bear Lake, a large body of water on the Utah-Idaho boundary, has been made to serve as a storage reservoir, though it is situated about 75 miles from the nearest of the large plants, at Grace, Idaho; 80 miles from the Cove plant; 100 miles from the Oneida plant; and about 170 miles, as the stream flows, from Wheelon, Utah, the farthest of the "Big Four." (Fig. 1.)

Under the most favorable conditions it requires at least 30 hours for water from the lake to reach the nearest plant

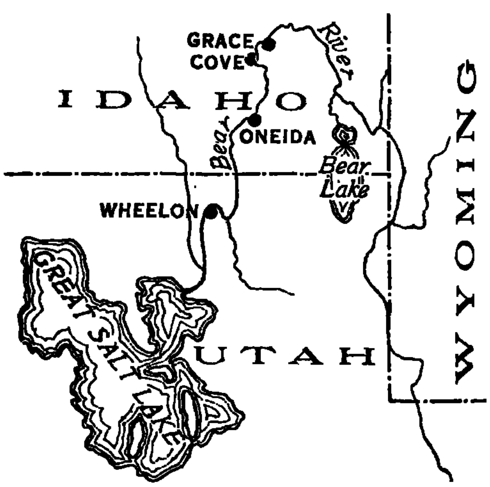

FIG. 1.

at Grace, and it very frequently requires as much as 48 hours of flowing time. In winter, when there is loose ice, slush, snow, or any considerable blockading from any cause, the flowing time is much greater still. The flowing time to Wheelon is practically double that to Grace. Only the plant at Oneida has a small auxiliary storage reservoir, the rest being solely dependent on the stream flow.

"Thus it will be seen," according to G. I. McFarland, superintendent of the Grace plant, "that every move made in the regulation of water is based absolutely on predictions of conditions that will obtain 36 hours later." And according to Chief Dispatcher H. S. Buchanan, the prediction of weather conditions and factors affecting stream height, as well as the demands for power from the various plants, must always be foreseen over as great a period of time as possible.

The utilization of water above the plants for irrigation in summer varies greatly from day to day with the general weather conditions and with the stages of the crops. Heavy showers will give a certain increase in the flow of streams from the immediate watersheds affected within a certain length of time and for a certain duration, and if the showers be sufficiently heavy in the agricultural regions there will be less irrigation water used for a few days after the storm. The problem of water regulation for power purposes varies also with the geographical distribution and the amount of precipitation from such storms. On the other hand, spells of dry, hot weather increase the demands for irrigation water and deplete the available supply correspondingly.

Numerous weather stations are maintained by the company, some of them having the status of cooperative stations of the Weather Bureau, from which reports are compiled daily in the central offices of the company at Salt Lake City for direct application to the problem of water regulation. Daily measurements of the flow of Bear River and of important irrigation canals near the lake and the Grace plant are made and dispatched to the power department, and once a week the discharge of all tributaries and irrigation canals between the lake and Grace is measured for correlation with all other conditions affecting the flow.

The company thus knows approximately from day to day how much water is available, how much power it will produce, and whether the water supply is increasing or decreasing. By July 1 the decreasing flow of all streams makes it necessary to release the flow from Bear Lake, through gravity outlets and later by pumping, to supply the gradually increasing demands on the Bear River plants. However, this water is extremely precious in dry seasons—and no one can foresee definitely that the coming few months will not be otherwise—hence it is doled out as economically as possible, withholding every foot that is not certain to be needed, a regulation which during the month of July, 1918, was so carefully applied that less than one-half of 1 per cent of the flow was wasted over the spillway at Grace.

Each day the chief dispatcher and the superintendent of power determine from the load carried the day before and the demands for power on the day following, with the weather and water conditions over the system, just what redistribution of electricity production in the various plants must be made, and particularly how much of the load is to be carried by the Bear River plants. This means in turn the determination of the amount of water to be released from Bear Lake, always remembering that the lake is from 30 to 48 hours distant, measured by the stream flow.

In winter a very troublesome condition is that of mush-ice formation, which is produced in very cold weather as the water passes over the many stony rapids. This congealed but unsolidified water lodges very readily against every obstacle and forms more or less extensive blockades here and there in the rougher parts of the stream. Such conditions must not only be anticipated, but must be quickly located and removed when formed. Usually the only means of removing such accumulations is by hydraulic pressure, produced by a crest of flood water from the lake, and this is often a slow process and results at times in field flooding.

Anchor ice, which forms in extremely cold weather on all protruding rocks and other objects where waves, splashing, or spray reaches is also very troublesome and may form a very effectual jam that is hard to dislodge. A heavy snowstorm tends to slow down the rate of stream flow, if it does not prove sufficient to produce a condition similar to mush ice. If the stream becomes well frozen over and a fairly constant discharge can be maintained, there is very little open water (only in the rapids), and consequently little trouble occurs until the ice goes out. It is sure to go out with more or less clogging in springtime, if not in a winter thaw, but a winter rain, not attended by sufficient duration of warmth to thaw the ice, is even more disastrous, unless the flow can be regulated to allow all water to pass under the ice.

The daily publications and reports of the Weather Bureau, especially the forecasts, are utilized freely in the consideration of this daily problem of water regulation, the superintendent of power having made intensive use of the weather map until it was suspended during the war, in amplifying the general forecasts for the specific problems in his own region. During the past winter (December, 1918, to March, 1919, inclusive) the State forecasts were amplified at the Salt Lake City office of the Bureau for the Bear River region, and the conditions prevailing over the northwestern States were given to the officials of the company by telephone each morning for their consideration in the water regulation problem.

THE COLORADO RIVER.

By FREDERICK H. BRANDENBURG, District Forecaster.

[Dated: Weather Bureau, Denver, Colo., July, 1916.]

SYNOPSIS.—This paper concerns the method of river-stage forecasting for the Colorado River and its principal tributaries, the Green, Grand, and San Juan Rivers. A brief description of the topographic features and courses of these streams is given. Attention is given to temperature conditions, as these to a large extent control the melting of the snows, which in turn make up much of the water supply. Two rating tables supplement the text, covering the Green and the Grand Rivers, respectively.—H. L.

The Colorado River is formed by the junction, in southeastern Utah, of the Green and Grand Rivers, and is joined by the San Juan River, its most important tributary, a few miles north of the Arizona-Utah State line. (See Fig. 1.)

The Green River rises in the mountains of southwestern Wyoming, and thence flows southward. From its source to its junction with the Grand River the Green is 425 miles in length. Near the Colorado-Utah State line it receives the waters of the Yampa and White Rivers, which drain northwestern Colorado.

The Grand River, which rises on the western slope of the Continental Divide in central Colorado, is joined by the Gunnison River at Grand Junction, Colo., and also by the Dolores, which drains the western slope of the San Juan Mountains, a short distance above the junction of the Grand and Green Rivers.

The San Juan, which rises on the southern slope of the San Juan Mountains, a part of the Continental Divide in southwestern Colorado, is about 200 miles in length.

In southeastern Utah and northern Arizona the Colorado River flows in a deep, rocky gorge, or canyon, through a region practically uninhabited, and the conditions are very similar along the Green and Grand Rivers for about 125 miles above their junction.

The drainage area of the Colorado River falls naturally into three divisions, the low-lying desert region, the elevated plateau region, and the mountain region. Each division has its characteristic climatic features. The lower division extends from the Gulf of California to the most easterly part of southeastern Nevada; the middle division from southeastern Nevada to the rating stations at Elgin, Utah; Fruita, Colo.; and Farmington, N. Mex.; and the upper division includes the area above such stations. The upper division is bordered on the north and east by the Continental Divide and on the west by ranges of high mountains.

The main flow of the Colorado comes, of course, from the snowfall in its upper reaches. The flow, however, is seldom large except during the periods of melting of the snow in the mountains. The summer rise usually occurs in June. The middle division contributes a considerable volume of water during March, April, and often during the first half of May from the melting of snow on the high table-lands. Practically no flow is received from snowfall in the lower division, although in the northern part of that division there are mountains which rise to an altitude of several thousand feet.

The mountainous nature of the country and the lack of telephone and telegraph facilities prevent the establishment of gaging stations on any part of the upper Colorado River. The usual method of predicting stages from gage readings at upstream stations on the same river is therefore out of the question, and results as unsatisfactory almost invariably attend an attempt to predict the stages of water on the main river from gage heights on the three rivers uniting to form it because they are so widely separated and their flow varies so greatly, a different method of arriving at results is necessary.

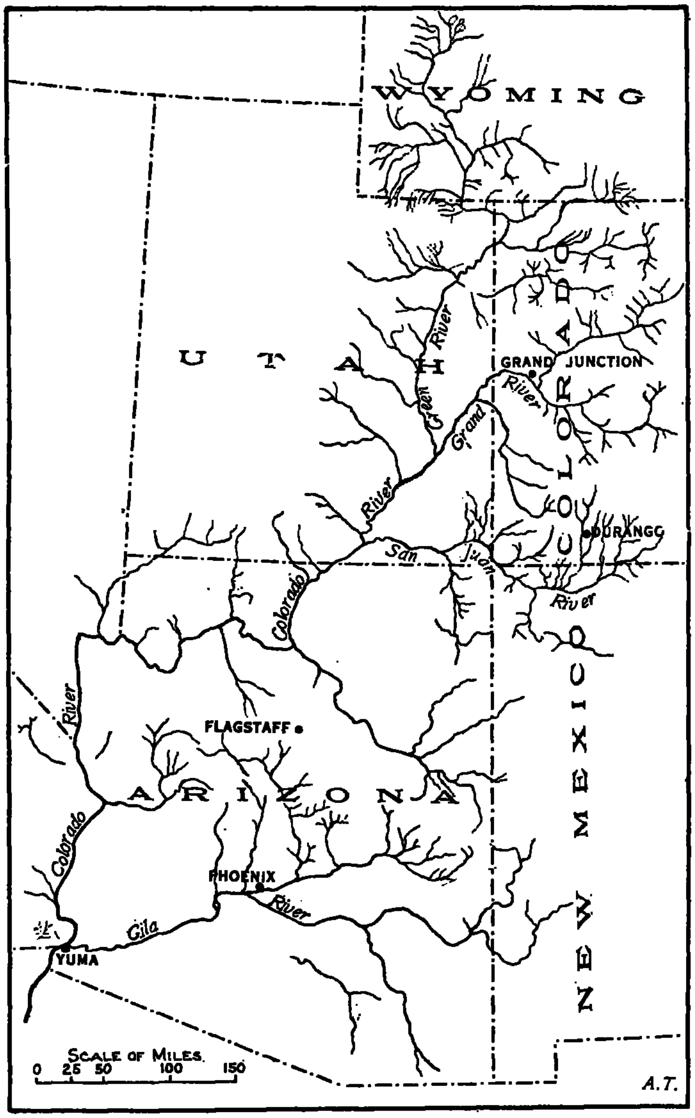

FIG. 1.